Synthesis of Moored Observations Collected During the IWISE 2011 Field Program in the South China Sea

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LONG-TERM GOAL

The long-term goal is to enhance our understanding of coastal oceanography by means of applying simple dynamical theories to high-quality observations obtained in the field. My primary area of expertise is physical oceanography, but I also enjoy collaborating with biological, chemical, acoustical, and optical oceanographers to work on interdisciplinary problems. I collaborate frequently with numerical modelers to improve predictive skill for Navy-relevant parameters in the littoral zone.

OBJECTIVES

The objective of this grant is to track the three-dimensional evolution of highly nonlinear internal waves (NLIW) in the South China Sea from their generation in and around the Luzon Straits to full maturity in the western deep basin.

APPROACH

The approach is to perform a joint analysis of data sets collected during a major ONR-sponsored field program in northeastern South China Sea during 2010-2011. Called the Internal Waves in Straits Experiment (IWISE), the program was a logical follow-on to the Nonlinear Internal Waves Initiative (NLIWI) but focused more closely on the generation problem. A large team of investigators from the U.S. and Taiwan conducted the experiment from both U.S. and Taiwanese research vessels. A comprehensive set of moored and shipboard observations were collected near the supposed generations sites (Figure 1) by M. Alford (SIO), J. Nash (OSU), and A. Pickering (OSU). Moving west from there, a 3 x 4 array of twelve inverted echo sounders with pressure (PIES) were deployed between 118° 30'E and 121° 30'E (Figure 1) by D. Farmer (UVic) and J. H. Park (Inha Un.). Finally, two tall moorings were deployed along 118°E (Figure 1) by Y. J. Yang (IONTU) and S. R. Ramp (Soliton). All these projects sampled with sufficient speed and spatial density to observe the evolving nonlinear internal waves. Initial papers from each project individually have been published [Alford et al., 2011; Ramp et al., 2015]. The task under this grant (and companion grants to M. Alford and J. Nash) is now to marry up the results from all three projects into a comprehensive statement of how the waves and internal tides evolve as they propagate westward across the sea. Some of the key questions to be addressed include:

- What is the longitudinal variation of internal wave energy? This subject has been completely unobserved up to this point.
- What is the trans-basin energy budget?
- Where are the sources located for the NLIW observed in the far field?
- How do the Kuroshio Current and mesoscale eddies along the propagation path impact the wave energies and arrival patterns in the far field?
- How do tropical cyclones and typhoons alter the structure of the evolving waves?
- Can we improve our predictive skill for large nonlinear wave arrivals in the far field?

WORK COMPLETED

The individual data sets have been collected and the data organized. A kick-off IWISE synthesis workshop has been organized for November 11-12 in Carmel, CA. All the above named investigators will attend plus additional scientists who have joined in under their own funding. These include Oliver Fringer (Stanford, NOPP funding), Emily Shroyer (OSU, ONR Young Investigator funding), and Kristen Davis (UC Irvine, Academia Sinica funding). They bring additional perspective on internal wave modeling and very shallow water wave breaking and dissipation, respectively. A postdoctoral investigator working with M. Alford at SIO has also joined the group (Arnaud Le Boyer).

RESULTS

A first look at the basin mooring data suggests a few topics that are ripe to explore.

- There were many more wave arrivals at mooring N than at mooring S (Figure 2)
- Wave arrivals started sooner and ended later at N than S
- All waves arrivals at S lead the arrival of the same wave at N
- The lead for a- vs. b-waves was different, 4 hours for a-waves and 2.5 hours for b-waves. This implies different sources for the two types of waves.
- At both moorings, b-waves propagated in a more southerly direction than a-waves (Figure 2)
- All waves at buoy S propagated in a more southerly direction than buoy N (Figure 2). (The wave fronts were not linear.)
- At least one large anticyclonic warm-core eddy influenced the observations (Figure 3).

IMPACT/APPLICATION

Turbulent breaking internal waves in the mid-thermocline region have a profound effect on navigation and acoustic propagation. Improved understanding and predictive skill provides tactical advantage in that environment.

TRANSITIONS

S. R. Ramp has made one presentation at NRL Stennis under separate funding. A second visit is anticipated. Dr. Ramp retains a courtesy appointment at the Naval Postgraduate School and has regular contact with the U.S. Navy via officer-students and faculty there.

RELATED PROJECTS

This project is funded under three separate grants to S. R. Ramp (Soliton), M. Alford (SIO), and J. Nash (OSU). Travel funds to facilitate collabration with international colleagues was provided via Soliton Ocean Services, Inc. A separate grant to S. R. Ramp to study NLIWs shoaling on the continental slope NE of Dongsha Island is highly related.

REFERENCES

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PUBLICATIONS

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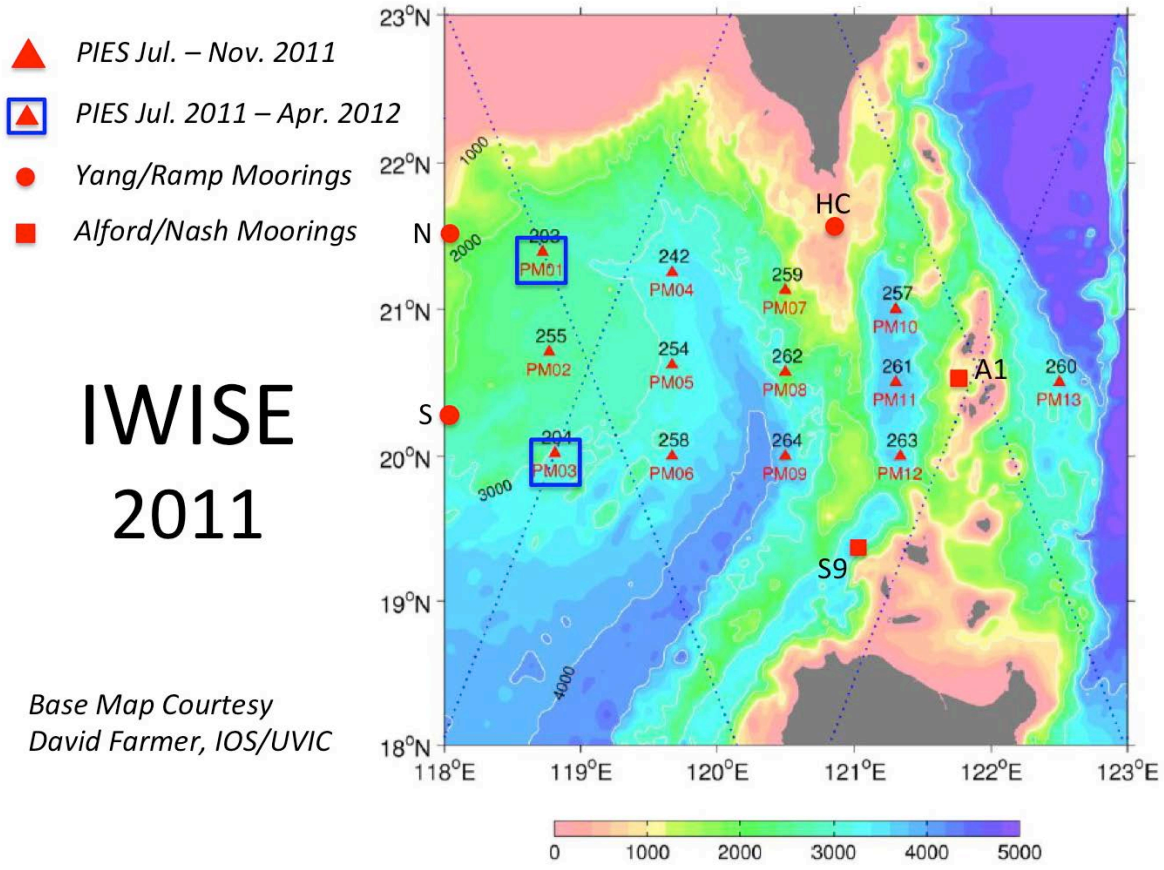

Figure 1. Location map of the observations obtained during the IWISE 2011 field program. A joint analysis will be performed on these data.

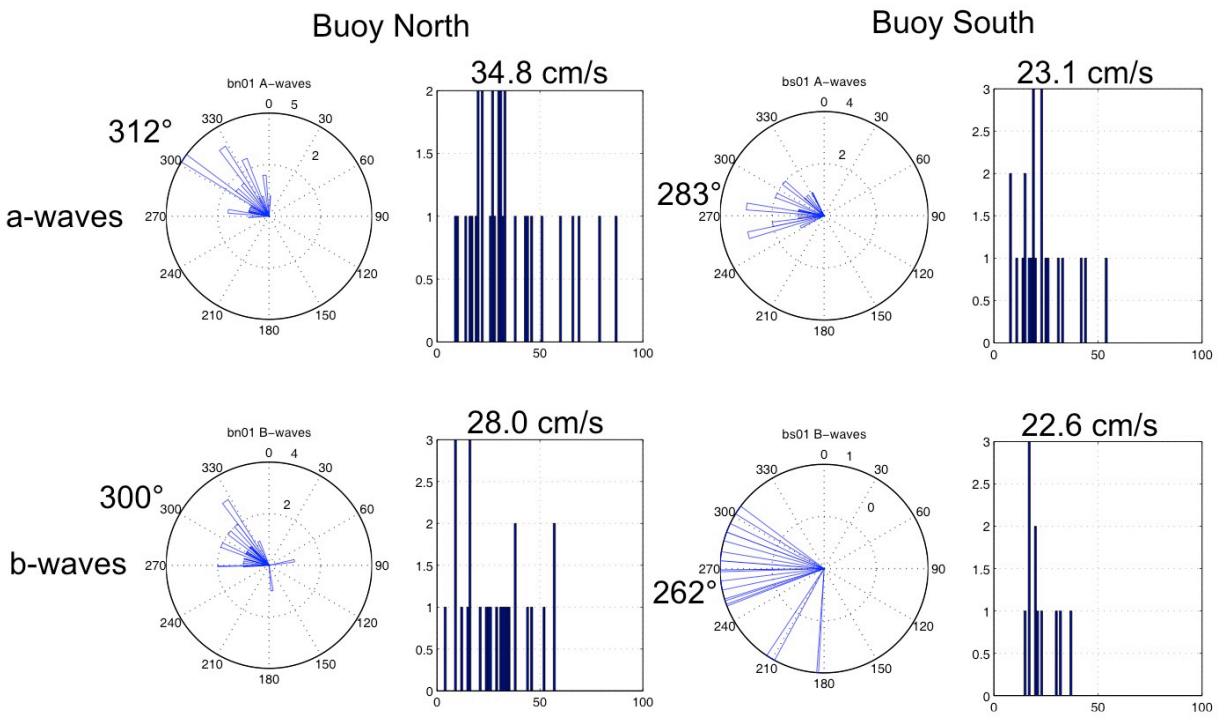

Figure 2. Histograms of wave arrivals (all NLIW with amplitude greater than 20 cm/s) at basin moorings North (N) and South (S). More waves were observed at N than S.

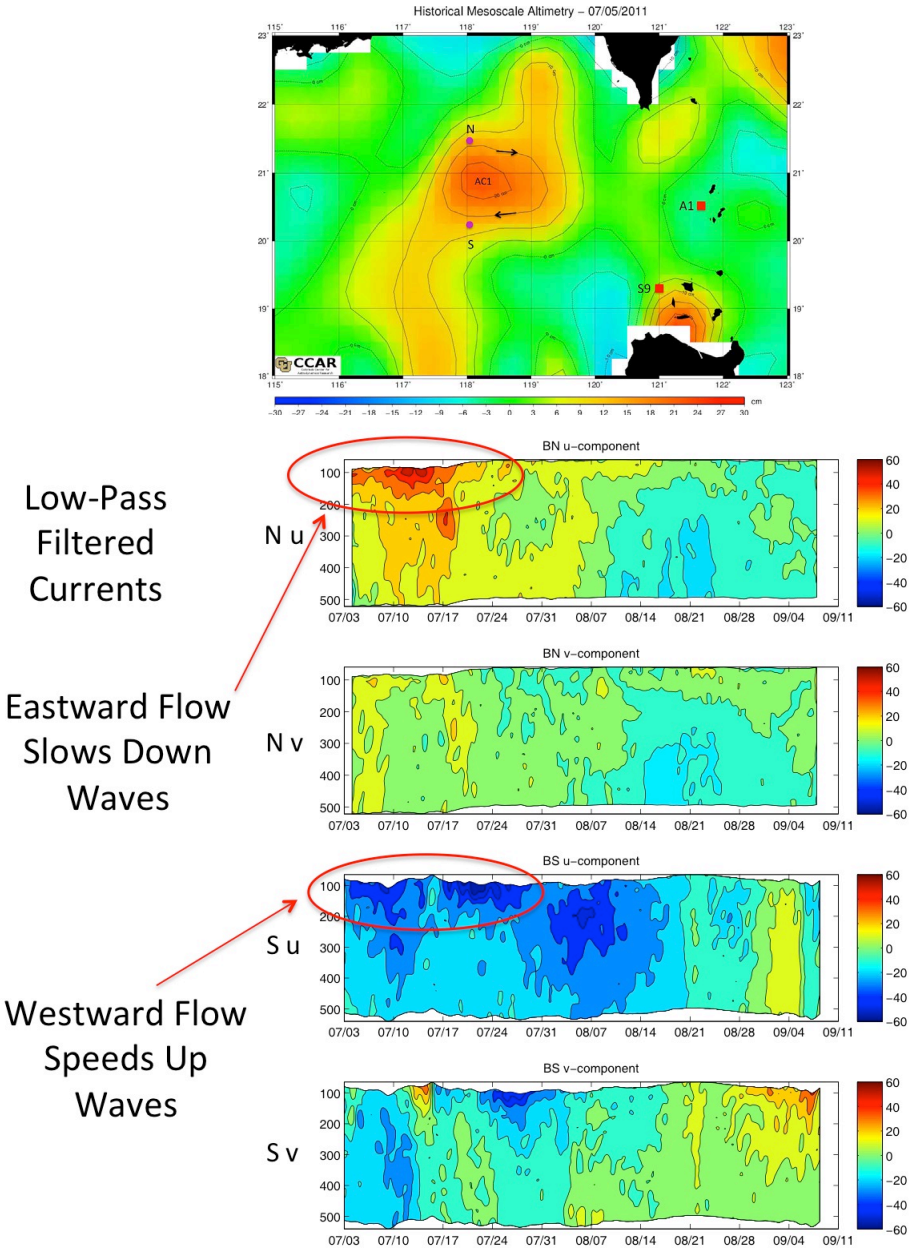

Figure 3. Eddy-induced currents at moorings N and S during July 2011. The position of the eddy relative to the moorings is shown in the top panel using altimetry. The low-pass filtered currents are shown in the bottom panel, eastward at N and westward at S. [Altimetry courtesy of the Colorado Center for Astrodynamics Research (CCAR).]